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Psychometric properties of the Movement Assessment Battery for Children-Checklist as a screening instrument for children with a developmental co-ordination disorder

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Background. The Checklist of the Movement Assessment Battery for Children (M-ABC) was developed to screen children for movement difficulties in the school situation. However, the psychometric properties of the Checklist have not been investigated in detail.

Aim. The psychometric properties of the M-ABC Checklist were investigated including its usefulness as a screening instrument.

Samples. A group of 120 children, 6 to 11 years old, randomly selected from mainstream schools and a group of 64 children, 6 to 9 years old, referred for assessment of their motor functioning.

Methods. A reliability analysis was performed to investigate whether the 48 items of the Checklist measure the same construct. Construct validity was investigated by means of a factor analysis. And lastly, the sensitivity, specificity and positive predictive value of the Checklist were investigated by comparing the performance of children on both the Test and Checklist of the M-ABC.

Results. The items of the Checklist measure the same construct. Seven factors were obtained after factor analysis, revealing that the Checklist measures a broad range of

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motor skills. The Checklist met the standards for sensitivity in all age groups, except in the 8-year-old group, where too many children with motor problems were not detected. With the exception of the 6-year-old children, specificity was poor. The positive predictive value was acceptable, except for the 7-year-old children.

Conclusion. the Checklist proved to meet standards for reliability and most aspects of validity. Its use by teachers for screening children with movement difficulties can be recommended.

According to the diagnostic criteria of the diagnostic manual of mental disorders (DSM-IV, APA, 1994), children with a developmental co-ordination disorder (DCD) perform substantially below that expected given their chronological age and measured intelligence in daily activities that require motor co-ordination. This interferes with academic achievement or activities of daily living and is not due to a medical condition. Early detection followed by early intervention of children with DCD is significant for various reasons. First, contrary to earlier views, the motor problems of these children are not temporary but persist over time even into adolescence (Cantell, Smyth, & Ahonen, 1994; Geuze & Börger, 1994; Hellgren, Gillberg, Bågenholm, & Gillberg, 1994; Losse *et al.*, 1991; Lunsing, Hadders-Algra, Huisjes, & Touwen, 1992). Second, next to motor problems, high rates of co-morbidity occur across all ages, such as cognitive and behavioural problems, and poor psychiatric outcome (Hellgren *et al.*, 1994; Losse *et al.*, 1991; Schoemaker & Kalverboer, 1994; Soorani-Lunsing, Hadders-Algra, Olinga, Huisjes, & Touwen., 1993). These problems might be prevented by early intervention according to the positive results of several studies regarding the effectiveness of intervention for these children (Schoemaker, Hijlkema, & Kalverboer 1994; Sigmundsson, Pedersen, Whiting, & Ingvaldsen, 1998).

Especially, teachers seem to have the opportunity to identify children with motor problems as they are able to observe all kinds of motor skills in both classroom and playground activities. But the systematic identification of children with DCD in schools is dependent on the availability of adequate screening methods. So far, mainly motor tests were used for the identification of children with DCD for research purposes (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001; Wilson & McKenzie, 1998). However, the administration of a motor test is too time consuming, and hence too expensive, for screening of children in schools. Although less objective than a standardised motor test, questionnaires may provide a relatively fast impression of a child's level of motor competence. At present, several questionnaires are available for the identification of children with DCD. In Canada, the Developmental Coordination Disorder Questionnaire (DCDQ) was developed as a parent questionnaire (Wilson, Kaplan, Crawford, Campbell, & Dewey, 2000). In addition, in 1992, one of the most popular tests in studies on children with DCD, the Movement-ABC (M-ABC), was extended with a teacher questionnaire, the M-ABC Checklist (Henderson & Sugden, 1992). The present study will focus on this questionnaire. The M-ABC Test provides an indication of a child's functional motor skills. The M-ABC Checklist is a criterion-referenced questionnaire (Wright & Sugden, 1996a). On the Checklist, teachers rate the performance of children on 48 items reflecting motor activities common in day-to-day school life of children from 4 to 12 years of age (Sugden & Sugden, 1991). According to the theoretical framework of Gentile and her colleagues, these items are classified in four sections (12 items in each section) in order to reflect the difficulty level of the activities (Gentile, Higgins, Miller, & Rosen, 1975).

According to the authors of the M-ABC, 'the Checklist provides an economical means of assessing groups of children through classroom assessment and is ideal for screening purposes' (Henderson & Sugden, 1992, p. 3). However, although at face value the M-ABC Checklist appears to have potential usefulness for screening purposes, there is as yet insufficient evidence on its reliability and validity (Burton & Miller, 1998). Information about a limited range of psychometric properties of the Checklist is provided in the manual of the M-ABC and in several papers (Henderson & Sugden, 1992; Sugden & Sugden, 1991; Wright, Sugden, Ng, & Tan, 1994; Wright & Sugden 1996a), but more comprehensive validation is needed. Therefore, the aim of the present study is to investigate systematically aspects of the reliability and validity of the Checklist. Two groups of children were selected for this purpose, a group consisting of children randomly selected from mainstream schools in the Netherlands, and a group of children referred for their motor problems to physiotherapists.

For an instrument developed to measure motor performance, it is important to know whether the items included in the Checklist measure the same construct. According to Wright *et al.* (1994), the correlation between the scores on the four motor sections separately and on the total of the four sections varied between .33 and .86 in a sample of 212 7- and 8-year-old Singaporean children. However, the correlation between sections does not provide sufficient information about the degree of homogeneity among individual items within sections. Therefore, in the present study, Cronbach's alpha will be calculated as a measure for homogeneity.

The validity of a measuring instrument refers to the appropriateness of the interpretation of the results on that instrument. The construct validity of the Checklist will be addressed, which is the degree to which the underlying traits of a test can be identified and the extent to which these traits reflect the theoretical model on which the test is based (Streiner & Norman, 1996). First, we will investigate the presumed increase in complexity of the activities included in sections 1 to 4 by looking at the mean scores of the children across the four sections. Second, an important aspect of construct validity is whether the constructs underlying the Checklist are supported by factor analysis. To our knowledge, this aspect has not been investigated previously. In addition, the discriminant validity of the Checklist will be studied, which refers to the ability of the Checklist to distinguish between children known to be deficient in motor ability (children in the referred group) and those presumed to be normal (children in the random group). As the Checklist was developed as a screening instrument, information about concurrent validity is extremely important. Consequently, in this study, the agreement between the Test and the Checklist of the M-ABC in classifying children as those with and without motor problems will be examined. In a recent study, the sensitivity of the Checklist appeared to be rather low (14.3%), implying that the Checklist failed to identify children with poor scores on the Movement-ABC Test (Junaid, Harris, Fulmer, & Carswell, 2000). Replication of these results is warranted considering the increasing popularity of the M-ABC.

Summarising, in this paper we will investigate: (1) which aspects of motor performance the Checklist actually measures (the reliability and construct validity); (2) whether the Checklist is able to discriminate between children with and without motor problems (discriminant validity); and (3) the validity of the Checklist as a screening instrument used by teachers for the identification of children with DCD (concurrent validity).

Method

Participants

A total of 184 children participated in this study divided into a random group and a referred group. The random group consisted of 120 children, 6 to 11 years old. This group was composed in the following way: physiotherapists throughout all parts of the Netherlands were asked to test children, randomly selected from mainstream schools in their neighbourhood. In order to avoid age and gender influences on the data we decided to include subjects until each of the six age groups consisted of 10 boys and 10 girls. The referred group consisted of 64 children, 6 to 9 years old, referred for further assessment of their motor functioning to a physical therapist by their general practitioner, because they were suspected of having motor difficulties. Again the children were equally divided across gender and age: 8 boys and 8 girls in each of the four age groups. A limited age range was employed for the referred group as referral for physiotherapy in the older age groups seldom occurs in the Netherlands. The inclusion criteria for the referred group stipulated that the subjects did not have any indication of a neurological or physical impairment.

Children in the random group all attended mainstream schools. In the referred group, 36% of the children attended mainstream schools and 64 % attended schools for special education. In this study, only children from special schools for children with learning disabilities were included. In general, children attending Dutch schools for learning disabilities experience difficulty with basic reading and language skills (80%) notwithstanding normal IQ (above 80). Problems with mathematics also occur but are less common. Children with mental retardation, autism, deafness, blindness or severe behavioural disorders attend different types of schools for special education, which were not included in this study. The high proportion of children with learning disabilities in the referred group is not unexpected as the rate of co-morbidity between DCD and learning disabilities was found to be about 50% in previous studies (Kaplan, Wilson, Dewey, & Crawford, 1998).

Materials

The Movement Assessment Battery for Children

The Movement-ABC developed by Henderson and Sugden (1992) has two parts: a Checklist and a performance Test. Both parts are designed to assess everyday motor competence of the child.

The M-ABC Checklist is designed for teachers. It can be used both as a screening instrument as well as a means for planning intervention. The motor part of the Checklist is divided into four sections, with 12 items in each section. The first four sections consider the child's performance in progressively more complex situations: (a) child stationary-environment stable, (b) child moving-environment stable, (c) child stationary-environment changing, and (d) child moving-environment changing. The items in the four sections are scored on an ordinal scale ranging from 0 to 3. The scores of all 48 items are summed together to get a total score. The total scores for 6-, 7-, 8- and 9+ year-old children can be transformed to percentiles based upon the norms of the Checklist. As the English norms did not appear to be valid for the Dutch population, the norms from the Dutch standardisation were used (Smits-Engelsman, 1998). The higher the percentiles the better the performance. According to these norms, the children can be divided into a normal performing group (total scores

> 15th percentile), a borderline performing group (total scores between 6th and 15th percentile), and a group with deviant motor performance (total scores $\leq$ 5th percentile). The Checklist has adequate test-retest reliability (r = .89; Henderson & Sugden, 1992).

The M-ABC Test provides an indication of a child's motor functioning across fine and gross motor tasks. Performance is related to motor norms using age-dependent standardised scores. The M-ABC provides norms for children aged 4 to 12 years. There are four age-related item-sets, each consisting of 8 items measuring different aspects of motor ability; 3 items measure manual dexterity, 2 items measure ball skills and there are 3 items for static and dynamic balance. Children can score between 0 and 5 on each item, so that total score will vary from 0 to 40. The total scores can also be transformed to percentile scores which show the child's level of performance in comparison to that of peers. In the present study, the 15th percentile has been used as a cut-off criterion between normal and borderline/deviant motor performance. According to the data from the Dutch standardisation of the M-ABC Test (based upon a random sample of 549 children), the American norms are valid for the Dutch population (Smits-Engelsman, 1998). Therefore, these norms will be used in the present study. According to the manual, the test has acceptable validity and reliability (Henderson & Hall, 1982; Lam & Henderson, 1987). Inter-rater reliability for this test ranges from .70 to .89 while test-retest reliability is .75 (Henderson & Sugden, 1992). Research has shown that the test is very useful in identifying children with general motor difficulties (Henderson & Hall, 1982; Henderson, May, & Umney, 1989; Jongmans, Mercuri, deVries, Dubowitz, & Henderson, 1997; Laszlo & Bairstow, 1985; Smits-Engelsman, Henderson, & Michels, 1998; Sugden & Wann, 1987).

Procedure

The classroom teachers of the children in both the random and the referred group were asked to complete the M-ABC Checklist. No special training in completing the Checklist was given. All teachers received a one-page written instruction on how to complete the Checklist. In addition, oral information was given on the best strategy to deal with the questions (decide whether a child can or cannot do the task, and consider how well they perform). Before completion of the Checklist no information was given to the teachers about the level of motor performance of a child. In addition, children of both groups were administered the M-ABC Test by physiotherapists, trained in assessment and treatment of children. Testing was always conducted in a quiet room. Physiotherapists, of course, did not have prior information of the motor status of the children in the random group, but they knew that the children in the referred group were suspected of having movement difficulties.

Statistical analysis

Reliability

Cronbach's alpha was calculated to determine the degree of homogeneity among the 48 motor items of the Checklist together and the 12 items in each section separately using the data from the random group.

Construct validity

Spearman correlations were calculated between the four motor sections and the total scores on sections 1–4 of the Checklist. The increase in difficulty across sections of the Checklist was investigated on the data from the random group as a comparable sample was originally used by Henderson and Sugden (1992) in their validation study. To this purpose, a MANOVA repeated measurement was carried out with sections (4 levels) as within factor. In order to explore the factor structure of the Checklist, a factor analysis (principal components with varimax rotation) was carried out. As the Checklist is meant to be both a screening instrument and an instrument to be used for intervention planning, it is important to investigate the factor structure in a sample that includes both children with and without motor problems. As a consequence, the data of both the random and the referred group were combined for factor analysis.

Discriminant validity

The mean total scores of the random sample were compared with the mean total scores of the referred sample (ANOVA).

Concurrent validity

First, the number of children passing or failing the Checklist and passing or failing the M-ABC Test was calculated for the referred sample using the norms of the Checklist and the M-ABC Test. For both the Checklist and the Test, this was done for the 5th and 15th percentiles as criterion to separate children with normal motor performance from those with deviant motor performance, as both these percentiles are provided as cut-off criteria in the manual of the M-ABC. When the 15th percentile is used, both children at risk for motor problems (scores between the 5th and 15th percentile) and those with deviant motor performance (scores below the 5th percentile) are separated from children without motor problems (scores above the 15th percentile). The referred sample was used for this purpose as it is most efficient to determine the sensitivity and specificity of a test in a sample which contains about equal numbers of children with and without a movement problem. This is the case in the referred group as 52% of the children in this group score in the deviant range (below the 15th percentile) on the M-ABC Test. Next, the sensitivity, specificity, positive predictive value and hit rate were calculated for each pass/fail-criteria of the Checklist. Sensitivity refers to the percentage of children with problems according to the Movement ABC Test that is correctly detected by the Checklist. According to the norms of the American Psychological Association, approximately 80% is preferable (APA, 1985). Specificity is the percentage of children without problems who are correctly identified (90% is preferable). The positive predictive value is the percentage of the children who fail according to the Checklist and who have true problems on the Movement ABC Test (70% is preferable). The hit rate is the percentage of agreement between the Test and Checklist. No norms are available which percentage is preferable for hit rate.

Results

Reliability

The Coefficient Alpha for the random group was .96 for all 48 items together, .83 for section 1, .90 for section 2, .88 for section 3, and .85 for section 4. These coefficients are sufficiently high, suggesting that the items of the Checklist measure the same construct.

Construct validity

Structure of the Checklist

In order to be able to compare the data of the present study with the data provided in the manual of the Movement ABC, only the random group was used for analysis. First, the properties of the Checklist, as they are described in the manual of the test, have been investigated for the motor component (section 1–4). According to the structure of the Checklist, the scores are expected to increase from sections 1 to 4. Table 1 gives the means and standard deviations on each section and the sum of sections 1 to 4. The expected increase in scores from sections 1 to 4 was evident for both the total group and for all age groups individually except for the 6-year-old children where lower scores for section 4 than section 3 were obtained. The results of a MANOVA repeated measures revealed a significant main effect for sections, $F(3,324) = 112.804$, $p < .001$. In order to check whether the difficulty level of the sections progressed from 1, 2, 3 to 4, single factor repeated measures ANOVA were carried out. Alpha was set at .008 to correct for multiple comparisons using the Bonferroni correction. Section 1 differed significantly from section 2, $F(1,119) = 13.44$, $p < .001$, section 2 differed significantly from section 3, $F(1,119) = 71.874$, $p < .001$, but section 3 did not differ significantly from section 4, although a trend towards significance was found, $F(1,119) = 9.877$, $p = .002$.

Table 1. Mean scores and standard deviations (in brackets) for each motor section and the sum of sections 1 to 4 of the Movement-ABC Checklist for children across age in the random group

	Section 1	Section 2	Section 3	Section 4	Section 1-4
All	1.8 (3.0)	2.8 (4.0)	5.4 (5.2)	6.1 (5.1)	15.9 (15.6)
Age 6	3.1 (2.4)	4.3 (3.9)	10.8 (5.6)	10.5 (5.0)	28.7 (15.4)
Age 7	1.7 (1.6)	2.6 (3.6)	4.2 (3.0)	6.2 (4.1)	14.5 (10.0)
Age 8	1.6 (2.6)	3.3 (5.9)	4.5 (5.5)	5.8 (5.7)	15.5 (18.6)
Age 9+	1.4 (3.5)	2.1 (3.3)	4.2 (4.4)	4.7 (4.4)	12.4 (14.3)

Factor structure of the Checklist items

A factor analysis was carried out in order to investigate the factor structure of the Checklist. Before a factor analysis can be undertaken to determine which items in a test form coherent, relatively independent subsets, a check must be made for 'outliers' among the total item set. Outliers, defined as variables which produce very uneven splits between categories, must be excluded from factor analysis because their inclusion tends to decrease the correlations between variables (Tabachnick & Fidell, 1989). Using Tabachnick and Fidell's suggested exclusion criterion of a 90% – 10% split, only one item (item 4: push/pull wheeled vehicles from section 4) had to be deleted. In other words, this meant that on one item less than 10% of the children in the combined sample failed. Seven factors were extracted with an eigenvalue greater than 1, which together explain 73% of the variance. See Table 2 for an overview of the seven factors, their content, and factor loading. The first factor explained most of the variance

Table 2. Outcome of factor analysis on the 48 items of the motor part of the Checklist

	Factor 1 Ball skills	*Factor 2* Static balance, keeping rhythm, fine object manip.	*Factor 3* Dynamic balance	*Factor 4* Fine manipulation	*Factor 5* Avoiding obstacles	*Factor 6* Body scheme/ Locomotion	*Factor 7* Self-care skills
Throw an object into a container (overarm action) (210)	**.65**	.21	.42	.08	.13	.25	.11
Intercept and stop a moving object (303)	**.54**	.08	.35	.36	.30	−.02	.26
Catch a large approaching ball (304)	**.73**	−.09	.17	.23	.06	.10	.19
Catch a small approaching ball (305)	**.79**	.10	.005	.13	.01	.08	.23
Kick an approaching ball (306)	**.59**	.20	.27	.20	.34	.25	.14
Hit/strike a moving ball (307)	**.69**	.28	.22	.07	.12	.29	.06
Roll a ball for a moving child to catch or stop (308)	**.59**	.20	.27	.21	.34	.25	.03
Throw a ball for a moving child to stop or catch (309)	**.51**	.48	.39	.06	.30	−.05	−.04
Continually bounce a large ball while standing still (310)	**.51**	.41	.46	.03	.28	.12	.02
Use non-stationary apparatus, such as wings unassisted (402)	**.51**	.06	.43	.30	.08	−.29	.17
Run to catch an approaching ball (406)	**.78**	.26	.16	.15	.09	−.01	.06
Run to kick an approaching ball (407)	**.71**	.22	.20	.19	.13	.17	.06
Run to hit/strike an approaching ball (408)	**.81**	.24	.03	.05	−.02	.18	−.02
Use skills of striking/catching to participate in a team game (409)	**.55**	.35	.26	.12	.16	.29	−.06
Move around keeping control of a moving ball (410)	**.58**	**.54**	.28	.04	.17	.07	.10
Stand on one leg in a stable position (102)	.28	**.57**	.39	.13	.14	.09	.30
Demonstrate good posture when sitting or standing (105)	.05	**.64**	.15	.11	.37	.17	.25
Hold instruments using proper tension and grasp (106)	.16	**.66**	.07	.31	.28	.20	.09
Cut/draw/trace with precision/accuracy (107)	.17	**.72**	.01	.31	.26	.14	.14
Form letters, numbers that are legible (108)	.26	**.60**	−.01	.42	.20	.004	.12

Turn a rope with sufficient force to allow another child to jump or skip (311)	.43	**.64**	.25	.14	.04	.15	.24
Keep time to a musical beat by clapping hands (312)	.19	**.55**	.22	.29	.15	.43	.19
Move to enter a turning rope (411)	.30	**.70**	.26	.06	.01	.17	.13
Move in a variety of directions while keep time to a musical beat (412)	.17	**.60**	.35	.13	.11	.41	.17
Skip or gallop a distance of 15 feet (204)	.35	.38	**.57**	.27	.24	.13	.25
Hop in a controlled manner on either foot (205)	.35	.40	**.51**	.08	.21	.06	.44
Jump over/across obstacles (206)	.27	.19	**.75**	.26	.23	.12	.13
Use fixed playground apparatus such as balance beam (207)	.31	.10	**.66**	.42	.11	.15	.17
Manoeuvre through an obstacle course (208)	.26	.31	**.68**	.18	.12	.16	.29
Throw an object into a container (underarm action) (209)	.44	.20	**.53**	.13	.25	.34	.15
Pick up small objects (109)	.15	.22	.09	**.80**	.19	.27	.05
Use blocks, beads, puzzle pieces to complete task (110)	.17	.21	.20	**.81**	.23	.21	.09
Turn pages of a book (111)	.20	.34	.24	**.63**	.20	.05	.15
Participate in chasing games (405)	.22	.22	.40	**.53**	.15	.07	.17
Walk around avoiding collision with objects/persons (201)	.11	.27	.16	.22	**.81**	.26	.15
Carry objects around avoiding collision with objects/persons (202)	.15	.25	.20	.21	**.77**	.27	.12
Recognise own body parts (112)	.23	.34	.04	.08	.20	**.69**	.24
Demonstrate understanding of directional commands (212)	.32	.34	.15	.15	.26	**.66**	.22
Ride moving vehicles (403)	.19	.09	.09	.39	.31	**.57**	−.11
Put on and take off clothing without assistance (101)	.07	.3?	.23	.01	.16	.04	**.71**
Tie shoelaces, buckle belt (103)	.11	.45	.30	.13	.09	.23	**.56**
Demonstrate competence in personal hygiene (104)	.18	.13	.03	.34	.36	.07	**.64**
Amount of variance explained	49.6%	6.8%	4.5%	4.2%	2.9%	2.6%	2.3%

Note. Factor loadings above .50 are printed in bold type

(49.6%), and is formed by items involving ball skills in either open or closed task situations in a stable or changing environment. Factor 2 is formed by items measuring static balance, manipulation of fine objects and keeping rhythm. In factor 3, items measuring dynamic balance cluster together. Factor 4 contains items measuring fine manipulative ability, except one item measuring the ability to participate in chasing games. In factor 5, items cluster measuring the ability to avoid objects/persons, and in factor 6 items that involve knowledge of body scheme and directional awareness, in addition to the ability to ride vehicles. Lastly, factor 7 contains items measuring self-care skills.

Discriminant validity

For this part of the study, both data from the random group and the referred group will be used. We investigated the difference between scores on the motor part of the Checklist for the random group and the referred group. The difference between these groups was significant, $F(1,182) = 72.184$, $p < .001$, the mean score for the random group was 15.9 (*SD* 15.6) and 43.6 (*SD* 28.5) for the referred group. The children who were referred for treatment were judged to be less co-ordinated by their teachers than children in the random group.

Concurrent validity

The relationship between the Checklist and M-ABC Test scores was explored in two ways. First, the correlations between the scores on the Checklist and the total score on the Test were calculated (see Table 3). According to this table, all correlations between the sections and total scores of the Checklist and the M-ABC Test scores reached statistical significance.

Table 3. Correlations between scores on each of the four sections and the total scores on sections 1 to 4 of the Checklist and the total score of the Movement ABC for the random group

	Movement ABC Test
Section 1	.42**
Section 2	.44**
Section 3	.38**
Section 4	.35**
Section 1-4	.44**

**p<.01 (two-tailed)

In Tables 4 and 5, the sensitivity, specificity, and positive predictive value for each age group are presented for the referred group using the 5th and 15th percentile as cut-off points for the Checklist and the 15th and 5th percentile as cut-off point for the M-ABC Test, respectively. When we compare both tables, only slight differences become apparent when the 5th or 15th percentile was used as cut-off criterion for the M-ABC Test. As overall the 15th percentile seemed to give the best results, the results of this percentile will be presented below. According to these tables, the sensitivity which is the percentage of children with motor problems on the Test who are correctly

Table 4. Sensitivity, specificity, and positive predictive value of the Checklist across age levels in the referred group using the 15th percentile cut-off point on the M-ABC test

	Sensitivity[a]	*Specificity*[b]	*Positive predictive value*[c]	*Hit Rate*[d]
6 years	50% (*88%*)	88% (88%)	80% (*88%*)	69% (88%)
7 years	*80% (80%)*	45% (45%)	40% (40%)	35% (35%)
8 years	56% (67%)	71% (71%)	*71% (75%)*	63% (69%)
9 years	70% (*82%*)	67% (60%)	*78% (82%)*	69% (75%)
All	62% (79%)	66% (65%)	65% (70%)	64% (67%)

[a]Percentage of children who fail on the Test who were correctly identified by the Checklist.
[b]Percentage of children who pass the Test who were correctly identified by the Checklist.
[c]Percentage of children who fail on the Checklist who fail the Test (performed below the 15th percentile on the test).
[d]Percentage of agreement between Checklist and Test (percentage true positives + true negatives in sample).

Note. The 5th and 15th (in brackets) percentile of the Checklist is used as a cut-off criterion for deviant motor performance; the 15th percentile was used as cut-off criterion for deviant motor performance on the Movement ABC Test. Data that meet the desired standard are printed in italic.

Table 5. Sensitivity, specificity, and positive predictive value of the Checklist across age levels in the referred group using the 5th percentile cut-off point on the M-ABC test

	Sensitivity	*Specificity*	*Positive predictive value*	*Hit Rate*
6 years	50% (*83%*)	80% (70%)	60% (63%)	69% (75%)
7 years	*100% (100%)*	50% (50%)	40% (40%)	63% (63%)
8 years	57% (71%)	67% (44%)	57% (50%)	63% (56%)
9 years	67% (*89%*)	71% (43%)	*75% (73%)*	69% (75%)
All	65% (*85%*)	66% (55%)	57% (56%)	72% (67%)

Note. The 5th and 15th (in brackets) percentile of the Checklist is used as a cut-off criterion for deviant motor performance; the 5th percentile was used as cut-off criterion for deviant motor performance on the Movement ABC Test. Data that meet the desired standard are printed in italic.

identified by the Checklist was the highest when the more lenient 15th percentile was used as cut-off criterion for the Checklist. When looking at age differences, the sensitivity of the Checklist was sufficient when the 15th percentile was used as a cut-off criterion, except for the 8-year-old children. Regarding the specificity, which is the percentage of children without motor problems on the Test who also had good scores on the Checklist, the best results were obtained when the 5th percentile was used as cut-off criterion for the Test. The results for specificity hardly differed when either the 5th or 15th percentiles were used as cut-off criterion for the Checklist. The specificity only approached the desired rate of 90% for the 6-year-old children, but was too low for the older age groups. In general, the positive predictive value of the Checklist was satisfactory when either the 5th or 15th percentile was used as cut-off point for the Checklist. In those cases, the positive predictive value of the Checklist was sufficiently high for the 6-year-old and the children of 8 and above, but too low for the 7-year-old children. In case of the 7-year-old children, only 40% of the children who fail on the Checklist also fail on the Test. Thus, in this age range, too many false positives were obtained. The hit rate of the Checklist is best when the 15th percentile is used as cut-off criterion for the Checklist. The percentage of agreement varied between 63% and 88%, except for the 7-year-old children, where lower hit rates were obtained (35%).

Discussion

The aim of this study was to investigate several aspects of the reliability and validity of the M-ABC Checklist as a screening instrument for children with DCD. The Checklist turned out to be a reliable instrument as it concerns the degree of homogeneity among test items overall and within sections. Thus, we may conclude that the 48 items of the instrument measure the same construct, i.e., motor skill performance.

Regarding construct validity, we first investigated some underlying traits of the Checklist. The four motor sections of the Checklist are presumed to reflect the increasingly complex interaction between the child and the environment. It has previously been investigated whether the increase in level of complexity of the task also is reflected in an increase in section scores from sections 1 to 4. Surprisingly, the order of complexity of tasks across sections was not as predicted in a random sample of 6- to 9-year-old children, as section 3 appeared to be the most difficult (Henderson & Sugden, 1992; Sugden & Sugden, 1991). In order to alleviate this problem, some adjustments have been made in some items of section 3 of the Checklist, which appeared to be successful in a study in Singapore, except for the 7-year-old girls, who still scored poorest on section 3 (Wright & Sugden, 1996b). In our study, the increase in task complexity was reflected in an increase in scores from section 1 to 4 in the random sample for all age groups, except the 6-year-old children who obtained about equal scores for sections 3 and 4. These results suggest that in the Netherlands the more complex motor sections of the Checklist are also the most difficult, as the scores increase from section 1 to 4.

The nature and severity of the motor problems in DCD are known to vary widely across children (Sugden & Wright, 1998). Therefore, an instrument meant to screen children with DCD should measure performance on a broad range of motor skills. Wright and Sugden (1996a) conducted a factor analysis on the scores on the four sections of the Checklist and the eight items of the M-ABC test in a sample of 69 children with DCD. However, so far, no factor analysis has been performed on the 48 motor items of the Checklist. In order to fill this gap, a factor analysis was conducted in the present study. Seven clusters of motor skills were detected, including ball skills, dynamic balance skills, manipulation skills, skills related to body scheme, rhythmic skills, and the ability to avoid obstacles and to catch balls. Thus, the Checklist seems to cover the most important daily life motor skills fairly well. The factor that explained the most variance was ball skills. This finding might be due to the fact that a relatively large number of items in the Checklist address ball skills. Interestingly, in a study on the factor structure of the recently developed Developmental Co-ordination Disorder Questionnaire (DCDQ), the factor that explained most variance (37.1%) also involved ball skills in three out of six items loading on this factor (Wilson *et al.*, 2000). Apparently, ball skills is the most important domain in questionnaires measuring motor proficiency in children.

The clustering of items into four sections was not confirmed by our factor analysis. The aim of the test constructors was to cluster items in order to reflect the increasingly complex interaction between a moving child and its environment, based upon the theoretical framework proposed by Gentile and colleagues (Gentile *et al*., 1975). However, although the framework of Gentile *et al*. seems useful to cluster motor skills according to their difficulty level, this clustering does not reflect which skills are actually measured by the Checklist. According to the task specificity hypothesis of Henry (1968), only tasks measuring the same underlying motor abilities cluster together. If the Checklist is only used as a screening instrument, knowledge about the underlying factor structure is not necessarily needed. Nevertheless, as the Checklist can also be used for intervention planning (Henderson & Sugden, 1992), it may be helpful to know with which cluster of skills or underlying motor ability a child experiences difficulties.

The Checklist demonstrated good discriminative power between a random group of children and children referred for physical therapy. Apart from its discriminant validity, as the Checklist was designed as a screening instrument, the determination of the concurrent validity is even more important. In this study, the Checklist significantly correlated with the M-ABC Test (.44), indicating that both instruments assess motor skills. In two Canadian studies, the correlation coefficients between the Checklist and the M-ABC test (.51) (Junaid *et al*., 2000) and between a parent questionnaire (DCDQ) and the M-ABC Test (Wilson *et al*., 2000) appeared to be comparable (.51 and .59 respectively). However, the moderate height of these correlations indicates that the instruments share only one fifth to one third of the variance.

To assess the accuracy of the Checklist for screening of motor problems, the M-ABC Test was used as a criterion measure. Overall, the best results were obtained when the 15th percentile was used as a cut-off criterion for both the M-ABC Test and Checklist. Regarding the sensitivity of the Checklist, the standard for sensitivity of 80% was approached in all age groups, except for the 8-year-old children. More than 80% of the children who fail on the M-ABC Test were correctly identified by the Checklist. In the 8-year-old group, the Checklist did not detect a large number of children with motor problems on the M-ABC Test. These data are in contrast to the very low sensitivity rates (14.3%) obtained by Junaid *et al*. (2000).

According to Henderson and Sugden (1992), the Checklist will generally identify more children with motor problems than the Movement ABC Test, because with the Checklist a broader range of motor skills is evaluated. The data regarding the positive predictive value support this assumption. The standard of 70% (or about three of every four positively identified children on the Checklist) is reached for the 5th and 15th percentile as cut-off point of the Checklist. However, in case of 7-year-old children, the Checklist leads to over-identification: too many children will be positively screened for needless further diagnostic testing. For the other age groups, more than 70% of the children who fail on the Checklist will turn out to have a motor problem on the M-ABC Test. The data regarding the specificity of the test only approached the standard of 90% for the 6-year-old children, which means that about 90% of the children who pass the Checklist will also pass the M-ABC Test. For the remaining age groups, the specificity rates are poor. Thus, in the older age groups, too many children who pass on the Movement ABC Test will fail on the Checklist.

Henderson and Sugden (1992) studied the agreement between the Test and Checklist by comparing scores on the TOMI, the precursor of the M-ABC Test, of 16 children with Checklist scores above the 15th percentile and 16 children with Checklist scores below the 5th percentile. Agreement between the instruments was obtained in 76% of the children. According to Burton and Miller (1998), these data place the sensitivity of the Checklist for the identification of children with DCD into question. In the present study, the agreement between the instruments, as measured by the hit rate, was only better for the 6-year-old children (88%). The agreement for the 8- and 9-year-old children was comparable to the agreement obtained by Henderson and Sugden (1992). For the 7-year-olds, agreement between instruments was obtained in only 35% of the cases (when the 15th percentile was used as cut-off criterion).

The lack of agreement between the M-ABC Test and Checklist has been mentioned before (Sugden & Sugden, 1991; Wright & Sugden, 1996b). Accordingly, Wright and Sugden (1996b) advocate a two-step approach to identify children with DCD. Both the Test and the Checklist have to be employed, and a child must fail both instruments in order to be identified. This two-step approach seems to be in accordance with the formal criteria for the identification of children with DCD as listed in DSM-IV. According to these criteria, children with DCD have to perform significantly below that expected given their chronological age in daily activities that require motor co-ordination (criterion A). Although no instruments are specified to assess motor functioning and no cut-off criteria are supplied in criterion A, we may argue that this criterion is met if a child fails on the M-ABC test. In addition, the co-ordination difficulties of a child with DCD should interfere with academic achievement or activities of daily living (criterion B). Again, this criterion is not further specified. However, failure on the M-ABC Checklist may be regarded as an indication of problems with motor activities in the school situation.

Unfortunately, if this two-step approach was adopted in the present study, a number of children would have been missed, as they failed on the Test but passed the Checklist. The question is whether it is acceptable to discard the results of an objective instrument, i.e., the M-ABC Test, when the results of a far less objective instrument, the Checklist, are negative. In our opinion, in order to be acceptable as a screening instrument, the Checklist should miss no children with real problems. The Checklist has to function as a coarse sieve: it should identify all children who show signs of DCD. Afterwards, the Test should be used to confirm the diagnosis. According to our data, the Checklist does fulfil the function of a screening instrument, except for the 8-year-old children where too many children are missed.

Remarkably, the best results were obtained with the 15th percentile as cut-off criterion for both the Checklist and the Test. Generally, more lenient cut-off criteria are employed for screening instruments and more stringent criteria for instruments employed to confirm the diagnosis after screening. Although not described in the results section, we also investigated whether even better results could be obtained with the 25th percentile as cut-off criterion for the Checklist and the 5th and 15th percentiles as cut-off criteria for the Test. The sensitivity of the Checklist further improved using the 25th percentile, but at the cost of the specificity and positive predictive value (too many false positives).

How can we explain the lack of sensitivity of the Checklist for the 8-year-old children? First, the quality of the Checklist depends on the adequacy of the Movement ABC Test as a criterion measure. In the motor domain, no 'gold standard' exists, comparable to the WISC-R in the cognitive domain. In the present study, we chose to compare the Checklist with the Movement ABC Test, as both instruments are published as a package. However, only a limited range of motor skills is included in the Test. As a consequence, it is possible that both instruments detect different groups of children when different motor skills are included in each test. This explanation does not hold for the 6-, 7- and 9-year-old children, as the sensitivity proved to be acceptable in these age groups. According to the factor structure, the Checklist measures a broad range of motor skills, including the skills measured by the M-ABC Test. Therefore, we doubt whether the unsatisfactory results regarding the sensitivity of the checklist for the 8-year-old children were due to the use of an inadequate criterion measure.

Another possibility is that the results were due to the fact that class teachers completed the Checklist. Some schools have special physical education teachers. Consequently, class teachers are less able to evaluate performance of the children on all activities included in the Checklist, which might result in lower scores. This explanation is in line with recent findings by Piek and Edwards (1997), who compared the ability of physical education and class teachers to identify 9- to 11-year old children with motor problems using the Checklist. Physical education teachers were able to identify 49% of the children with motor problems, whereas class teachers identified only 25 %. As a consequence, the use of the Checklist by class teachers seems to be only recommended if they take their pupils for physical education. In the present study, we do not know which children did receive physical education from their class teacher or their physical education teacher. Therefore, it is hard to tell whether coincidentally more children who receive physical education from a specialised teacher were included in the 8-year-old sample of the present study. Larger age groups are needed to clarify this issue.

Summarising, the Checklist proved to meet standards for reliability and most aspects of validity. As it concerns concurrent validity, only for the 6-year-old children were the standards for sensitivity, specificity, positive predictive value and hit rate met. For the 9-year-old children, sensitivity, positive predictive value and hit rate were sufficient, but the specificity is too low, because of the large percentage of false positives. In case of the children of 7 years, only the sensitivity of the test was sufficient, but the specificity, positive predictive value and hit rate were very poor. For the 8-year-old children, the sensitivity was questionable because of the large percentage of false negatives: the Checklist failed to detect too many children with problems. Recently, the use of the Checklist as a screening instrument was discouraged because of its lack of sensitivity (Junaid *et al.*, 2000). We do not support this conclusion. Taken together, based on our data, the use of the 15th percentile as cut-off criterion can be recommended for screening of children with DCD in the Netherlands, except for the 8-year-old children. It is unclear why this age group turned out to be an exception. Future research on the Checklist should include a larger group of 8-year-old children in order to investigate whether the present data are an artefact from the present sample. For proper identification of children with DCD, it is not sufficient to screen children using the Checklist; the M-ABC Test needs to be used accordingly to confirm the diagnosis.

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